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Rainwater Harvesting in Informal Settlements of Windhoek, Namibia

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An Interactive Qualifying Project Report Submitted to the Faculty of

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in partial fulfillment of the requirements for the Degree of Bachelor of Science

Submitted to:

Robert Krueger, PhD

Fred Looft, PhD

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Abstract

Namibia is currently facing a water scarcity crisis, due to physical and social factors. For people living in informal settlements, rainwater harvesting is one way to ameliorate this situation. This project's goal was to use a participatory approach to develop a method for rainwater harvesting within the informal settlements of Windhoek. In addition to implementing a pilot system in the community of Hakahana, we set up a sustainable supply chain to allow residents to construct similar systems on their own.

Authorship

1. **Introduction** was written by G. Opperman.
2. **Background** was authored by G. Opperman, with the exception of **Namibia's Water Policy** and **Community Engagement**, written by V. Ward.
3. **Methodology** was contributed to by V. Ward and E. Grygorcewicz.
4. **Results and Findings** were authored by G. Opperman and S. Baker.
5. **Recommendations** were written by G. Opperman.
6. **Summary** was written by G. Opperman.

- **Appendices A and B** were authored by G. Opperman, based on field research by S. Baker and E. Grygorcewicz.
- **Appendices C and D** were written by V. Ward.
- **LaTeX formatting** was maintained by G. Opperman.

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Chapter 1

Introduction

In many locations around the world, access to basic human needs, such as water, is not guaranteed. Those living in the poorest of conditions cannot afford sufficient amounts of usable water, and must spend a disproportionate amount of their income just to meet their basic needs. The failure of water providers to properly address the global scarcity crisis exacerbates existing social problems, most notably poverty, public health issues, and even gender inequality.

> *Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical [water] scarcity, and 500 million people are approaching this situation. Another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage* (UNFAO, 2007).

Hydrologists define a water scarce nation as one that can only provide 1,000 cubic meters of water per person per year or less, meaning that lack of water becomes a severe constraint on human development (Ohlsson, 1997). Namibia, the driest sub-Saharan country in Africa, can only provide 360 cubic meters per person per year (Heyns, 2005). A variety of social and environmental factors, such as arid climate conditions, inequitable government policies, and others issues contribute to the current scarcity problem in Namibia. One of the biggest problems with this scarcity issue is that some organizations fail to properly engage affected communities in addressing their needs, which frequently undermines efforts to alleviate the problem. An alternative means of obtaining water is desperately needed in order to offset the growing demand for water.

> *Considering the acute problems of water scarcity that many are likely to face in the near future, it would seem prudent not to ignore the direct exploitation of nature's simplest and most fundamental source of renewable freshwater - rain* (Gould & Nissen-Petersen, 1999).

Creating a renewable community resource by harvesting rainwater can help offset the cost of potable water. In order for this solution to be successful, however, an approach must be developed where the community is a full partner in the planning and implementation of a water collection solution.

Project Goal

The primary goal of our project was to use a participatory research approach to develop a method for rainwater harvesting within the informal settlements of Windhoek. This included the implementation of flexible, reproducible solutions designed to harvest rainwater. Although there have been numerous case studies and projects focused on rainwater harvesting and participatory research methods, our project was one of the first that successfully integrated both in Namibia. Given the extreme limitations of community resources, this project adapted existing rainwater harvesting technologies to use found or recycled materials, setting up a sustainable supply chain for the continuation of the project beyond the time-frame during which we were able to participate.

Report Summary

The following chapter will provide a background for the project, including the global scarcity crisis, Namibian policies concerning water, common techniques for offsetting scarcity, as well as best practices for an approach to implement these techniques. Chapter 3 discusses the research methods employed in order to accomplish our research objectives. Chapter 4 details our findings regarding rainwater harvesting in the settlement of Hakahana, including the process by which we set up a sustainable water resource for the residents of the community, while Chapter 5 includes our recommendations for the expansion of rainwater harvesting beyond the scope of this project.

Chapter 2

Background

2.1 Introduction

To achieve the goal of using a participatory approach to develop a method for rainwater harvesting within the informal settlements of Windhoek, several pertinent background factors needed to be explored. Since this project dealt with the implementation of rainwater harvesting practices in a community, both social and technical background issues were examined. The background factors that informed this project were water scarcity, both globally and in Namibia, water policy, water harvesting, community participation, and specific information about the settlement in which we piloted the project. An examination of each of these topics provided the conceptual framework for understanding the issues at hand and developing an effective solution. (See Figure 2.1)

From our study of water scarcity, it became clear that it was necessary to investigate common methods for harvesting water. In order to determine the best way to implement such a system in the informal settlements of Windhoek, we directed our research towards the best practices to engage the

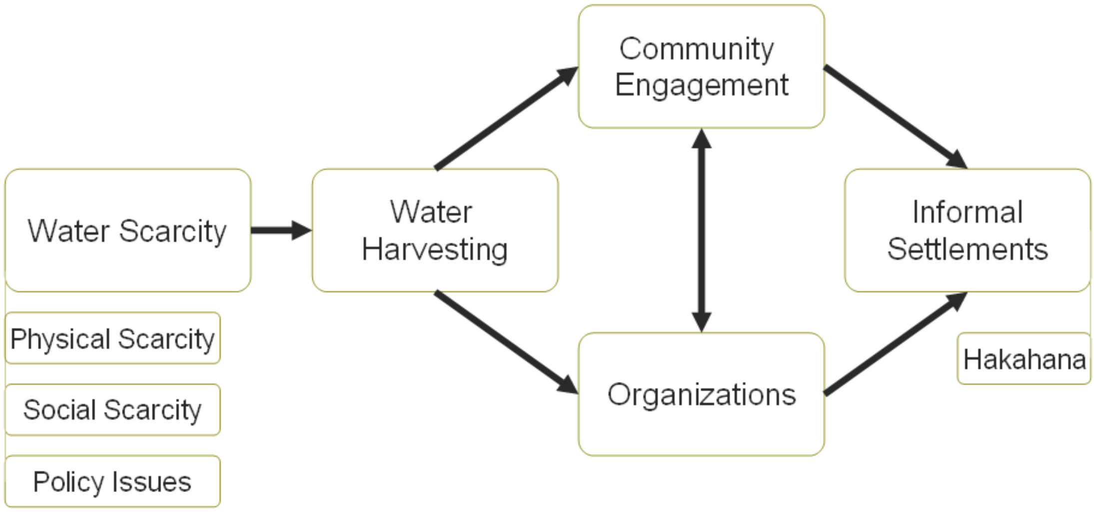


Figure 2.1: Background Conceptual Framework

community in participating in the project, as well as local organizations that could provide support. Finally, we searched for a community, Hakahana, that represented typical settlement conditions to implement our system.

2.2 Water Scarcity: A Global Problem

Like most commodities, water is a finite resource. The growing global demand for clean water, increasing poverty, and arid climates in some regions have all contributed to a growing water crisis (Kirby, 2004). "Throughout history human progress has depended on access to clean water and on the ability of societies to harness the potential of water as a productive resource. Water for life in the household and water for livelihoods through production are two of the foundations for human development" (UNDP, 2006). Despite the need, many people worldwide do not have sufficient access to usable water.

Global Scarcity

For those who live in the poorest of conditions, access to usable water is, for a number of reasons, difficult. For some of the world's poorest nations, lack of a sufficient water supply can stunt human development, limiting food production, economic development, and the protection of natural systems (Ohlsson, 1997). Well over 20% of the world's population experiences physical water scarcity, with another 25% facing economic shortages (UNFAO, 2007). A number of factors contribute to the global water crisis, including "poverty, inequality and unequal [gender] power relationships, as well as flawed water management policies that exacerbate scarcity" (UNDP, 2006).

Simply allowing access to clean water is not enough to guarantee that water needs are being met. In many places, the clean water supply is controlled, in whole or in part, by companies who charge for water. Even when a clean water supply is placed conveniently near a family's home, studies have shown that most people in water-stressed areas rely on multiple sources for clean water depending on the cost, availability, and a range of other external factors (UNDP, 2006).

Water shortages in the developing world also disproportionately affect women, exacerbating the preexisting gender inequalities. In water-scarce regions around the world, women often stay home from work or miss school in order to travel long distances to collect clean water (UNDP, 2006). In regions where equal access to education is the key to redefining archaic gender roles in society, women who must choose between school and providing a necessity of life for their family are, in practice, deprived of the inalienable right to an education (UNDP, 2006). In this sense, pre-existing gender inequality is reaffirmed by water scarcity.

Even though water is a finite resource, one of the primary causes for individual scarcity is not physical availability, but poverty. In practice, cost is the biggest factor for most when it comes to access to usable water; many impoverished people simply cannot afford to supply themselves with a basic amount of water. According to a recent UN Human Development Report, "When it comes to clean water, the pattern in many countries is that the poor get less, pay more and bear the brunt of the human development costs associated with scarcity" (UNDP, 2006). The poorest of families can pay as much as ten percent of their net income on usable water, while spending of even three percent indicates "hardship" (UNDP, 2006). The UN estimates that globally, two in three people lacking sufficient access to clean water live on less than two dollars a day, while one in three live on less than one dollar a day (UNDP, 2006).

The global scarcity crisis is most evident in many sub-Saharan African nations. In Namibia, the focus of this project, high poverty rates, arid climate, and other factors create inequity in the ability to afford a basic-level of usable water.

Scarcity In Namibia

As one of the driest countries in the world, Namibia is in a state of "absolute water scarcity" (Heyns, 2005). Although factors like poverty exacerbate the problem, the root cause of scarcity in Namibia is arid climate and lack of rainfall. With water as a limited natural resource, providers struggle to meet demand for potable water. Complicating short supply and growing demand, much of Namibia's water policy contributes to the problem through failure to properly address the issue of water scarcity.

Climate

Namibia is the driest sub-Saharan nation in Africa, with a relatively short rainy period. In Namibia, there are two identifiable seasons: summer, occurring between the months of November and April, and winter, occurring between May and October, with the most of the rainfall occurring between December and March. Due to the general increase in aridity from the northeast corner to the southwest corner of Namibia, it would be impractical and inaccurate to analyze rainfall patterns on a national scale. For example, the Kavango region of Northeast Namibia may receive greater than 800mm of rain per year while the Namib Desert region only receives 0-100mm of rain per year. Windhoek is fairly centralized with respect to the general diagonal drying trend through Namibia:

Windhoek would expect a rainfall range for a typical year to be 300-400mm. In most years, the rainfall usually yields levels that are closer to 300mm, but this was not the case in 2005-2006 when the rainfall for Windhoek in January alone reached 308mm, the wettest January ever recorded and the second wettest month ever recorded (Shigwedha, 2006).

Although Namibia is a water-stressed country, most people living in informal settlements have at least basic access to water. In some communities, people fill water containers via communal standpipes, using a pre-paid charge card to pay for the water. This program has been criticized as being unaffordable for settlement dwellers (IRIN, 2006). The gross national income of Namibia is per capita US$2,990, or a little more than US$8 a day (World Bank, 2005). However, this statistic reflects an average between the vastly rich and the overwhelmingly poor. Most people living in Namibia's informal settlements live below the average income level, making about US$43 a month, or less than US$1.50 a day (IRIN, 2006). The pre-paid card itself

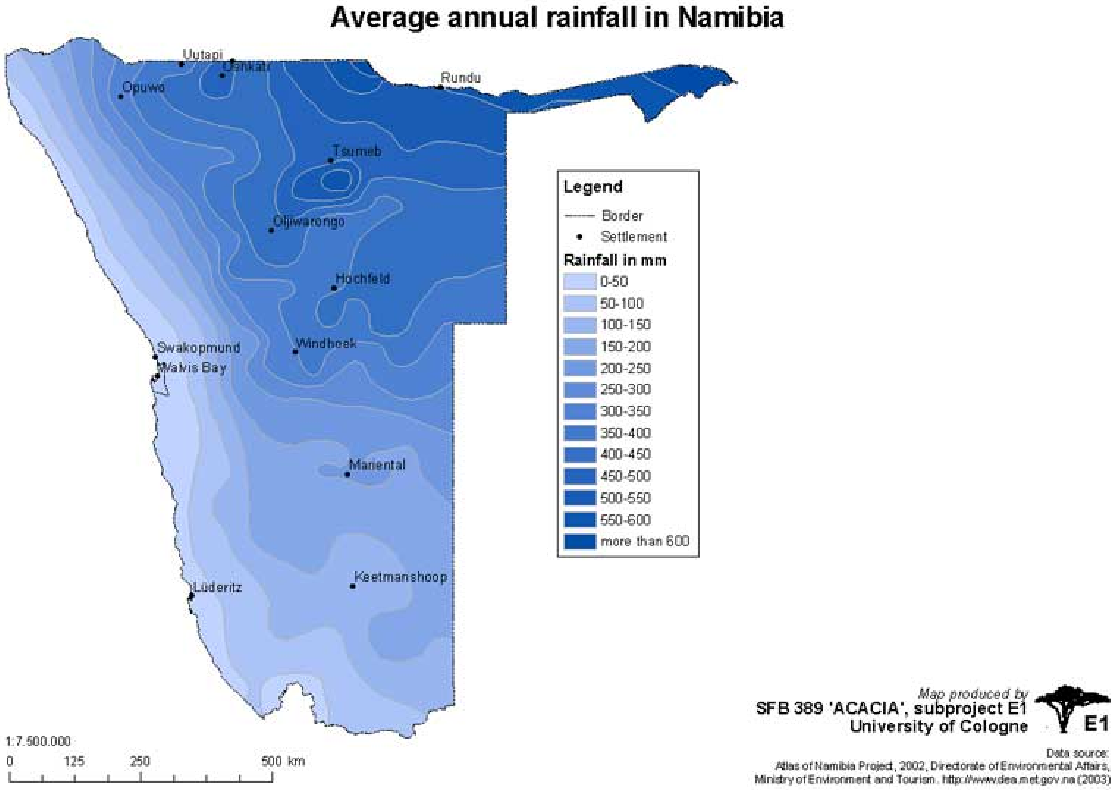


Figure 2.2: Geographic Rainfall Trends in Namibia

costs approximately US$15, which is a over a week's wages for most settlement dwellers (IRIN, 2006), and must be recharged regularly to actually obtain water. This makes the cost of access to clean water an undue burden that many have a great difficulty overcoming.

Namibia's Water Policy

Since Namibia gained independence in 1990, its water policies and view toward water issues have changed dramatically[1]. In 1997, the Namibia Wa-

[1] For a full history of Namibia's water policies, including rainwater harvesting, refer to Appendix D

ter Corporation Act created the parastatal Namibia Water Corporation, or NamWater, to take over bulk water processing and distribution from the Department of Water Affairs. NamWater is wholly owned by the Ministry for Agriculture, Water and Rural Development but independently run. When all bulk water assets were transferred from the government to NamWater in April 1998, the cost of water for Namibians increased dramatically.

According to Section 7(1)(a) of the Namibia Water Corporation Act, NamWater has the right to "determine and levy, in consultation with the Minister, tariffs on a full cost-recovery basis for water supplied" (Namibia Water Corporation Act, 1997). Full-cost recovery involves passing all costs for processing and distribution on the consumer without any government assistance. Before the creation of NamWater, water was almost completely subsidized, resulting in minimal water costs for consumers. The policy of full cost-recovery was adopted to make water processing and distribution financially sustainable and to encourage water conservation and responsible use (Bayliss, 2005). Years of completely subsidized water costs has led to some Namibians viewing water to have a low value, leading to mismanagement and over-usage.

The policy of full cost-recovery has led to a dramatic rise in water cost for most Namibians. This transition has been especially difficult on impoverished citizens and their communities. Many informal settlements and smaller communities outside Windhoek are unable to pay the fees assessed by NamWater since these fees have increased rapidly over the past several years. Some communities, especially those in more rural areas, only receive water for a few hours a day as a result of substantial outstanding debt to NamWater (Bayliss, 2005). This policy furthers the problem of non-payment because citizens do not receive the level of service they expect, creating a cycle of non-payment and mistrust (Pietil, 2005).

Informal settlements are particularly hard hit by this policy, because they have lower incomes and are less able to adjust to sudden, dramatic changes in the cost of utilities. Some households do not pay their water bills because of the belief that water should be provided free of charge by the government, like before the creation of NamWater. Others do not pay because they are too poor and unable to shoulder the substantial burden high water costs cause. This non-payment and resulting debt leads to further disillusionment with the system, creating a vicious cycle of non-payment and debt, ultimately resulting in the limitation of water availability. The highly centralized nature of water distribution in Namibia and the wide variety of community types, from urban, to suburban, to informal, makes creating a policy that can adequately serve all sectors of the population. The current pricing and bill collection system may work well for those in Windhoek proper or affluent suburbs, but those living in informal settlements are not served by current policies.

Namibia is taking some steps to change the water industry, but currently, not enough is being done to handle current problems and create long-term goals for water distribution and administration reform. Though the creation of NamWater led to dramatic changes in the water sector, often Namibia's water policies are created in response to crisis, and are not pro-active in protecting Namibia's water supply for the future. Namibia has, however dramatically increased water availability for citizens since independence and has invested heavily in building up the infrastructure, but it suffers from a lack of human capacity in creating policy changes and institutional reforms. Technically, the capacity for delivery of water exists, but will need to be significantly expanded in the coming years as water scarcity becomes a greater problem and the population increases. According to Bayliss (2005), Namibia's relatively small budget for water resources administration, infrastructure development, and operations is impeding reform and further growth.

The costs associated with water, especially for informal settlement residents, add to the already dire problem of physical water scarcity. Not only is water a valuable resource environmentally, but is also an economic burden for too many Namibians.

Worldwide, the water scarcity crisis is growing, as a number of social factors contribute to the problem. Poverty, gender inequality, and inadequate government policies all amplify water scarcity problems caused by arid climate and high demand. This problem is ever-present in the informal settlements of Namibia, where people spend a large portion of their income on water, due to the country's high costs associated with meeting water demand. The Namibian government's response to this impending crisis has been limited, due to a dearth of resources, limited technical capacity, and an overall lack of political commitment. Instead, the burden of overcoming scarcity has been passed on to the community level. Even when government policy fails to properly address water scarcity, it is still possible provide inexpensive, clean water to those in need through other means, namely, basic rainwater harvesting techniques.

2.3 Rainwater Harvesting

Rainwater harvesting is any method of collecting rainwater from natural or man-made surfaces to be stored and used for productive purposes such as human and/or livestock consumption, irrigation, household chores, and construction, i.e., for use in cement mixing. In wet climates, harvesting can provide enough water to meet almost all needs, while in arid climates, harvesting usually acts as a supplement to an existing water source. Harvesting in arid climates can be helpful because rains, which usually occur episodically, yield high volumes of water over short periods of time, providing an ample supply during rainy seasons. If designed and constructed properly, rainwater harvesting systems can collect and store water in a manner where the benefits quickly exceed the cost and, in many cases, costs can be greatly reduced by using discarded materials that are readily available.

The two main approaches to water harvesting are Micro-Catchment Water Harvesting (MCWH) and Runoff Farming Water Harvesting (RFWH) (Ben-Asher & Boers, 1981). MCWH deals primarily with collecting surface runoff and storing it in the root zone of another area, while RFWH is concerned with using diversion systems to route the water to a storage system.

A case study in the Loess Plateau of China, a semi-arid region with rain patterns much like Namibia, examined methods of constructing compacted micro-catchments in order to increase crop production (Gao & Li, 2001). While the study examined large-scale agriculture, the solutions proposed in the study could also be implemented for small-scale gardening. The study proposed using a mixture of locally available soils, compacted by simple rollers, in order to increase runoff which would then be collected into other areas using common methods of water diversion. The study proved a success, with results showing "that rainfall-runoff efficiency from such compacted plots was 33% of the total rainfall as compared to 8.7% from the untreated plots" (Gao & Li, 2001). However, soil erosion proved to be a problem during heavy rainfall, making this solution undesirable for locations in Windhoek with existing erosion problems. The researchers suggested methods of stabilization, such as the tire dams already in place in some informal settlements, but it is unclear from the study to what extent these measures were effective.

Taking another approach, there have been numerous studies concerning Runoff Farming Water Harvesting (RFWH) techniques in urban areas much like Windhoek's informal settlements. A subset of RFWH, Domestic Rainwater Harvesting (DRWH), focuses on collecting water from a surface, diverting it (usually with a gutter system), and then storing the water safely until it can be used (Thomas, 1998). The most common, and effective, surface collectors are corrugated metal sheets. "Corrugated iron is now widely used as a roofing material in much of the developing world. In Africa it is rapidly replacing traditional roofing materials such as grass thatch in rural areas. Since a well-constructed, corrugated, galvanized iron roof provides an ideal catchment surface, the potential for utilizing rainwater supplies is increasingly steadily in much of the developing world" (Gould & Nissen-Petersen, 1999). Most homes found in informal settlements in Windhoek use single sloped roofs, primarily because the cost of such roofs is less than a typical double-sloped roof. This design is ideal for rainwater catchment, as gutters are only needed on one side of the roof and less piping is needed to direct the water from the gutters to a storage tank or catchment system.

DRWH in Windhoek	
Cost of Water:	N$9.57/1000L
Potential Harvest:	10,480L/year
Water Savings:	N$100.29/year
Harvesting System:	N$80-220
Payoff Period:	1-2 years

Figure 2.3: Cost Effectiveness of Rainwater Harvesting for Windhoek, Namibia

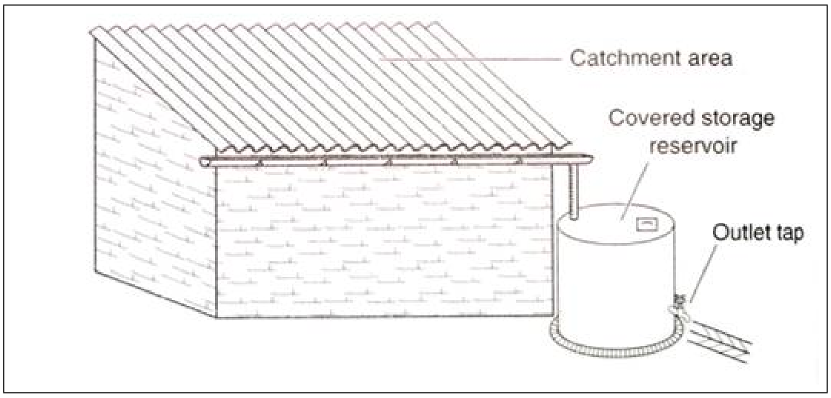


Figure 2.4: A Typical DRWH System (Gould & Nissen-Petersen, 1999)

While guttering can be constructed cheaply, the main disadvantage of DRWH techniques is the cost associated with storage (Thomas, 1998). Great care must be taken to protect water from algae and other contaminants that would render the water unusable. Proper storage for water can cost in the area of N$43 per cubic meter, and can range from personally owned storage drums to large, underground tanks shared by entire communities (Thomas, 1998). For Windhoek's informal settlements however, underground storage is not an option because of the dense rock that lies underneath the thin layer of soil. The cost of storage can be progressively overcome by adding units over time:

> *It is attractive to be able to engage with a new technology in easy stages, buying units of DRWH storage piecemeal over several years rather than having a massive outlay in year one. Finally, we note that splitting storage between several small tanks (rather than one large communal tank) offers greater security against tank failure and may reduce guttering costs* (Thomas, 1998).

This method has been proven in urban areas around the world, including Singapore, China, and East Africa, and shows promise for Namibians living in informal settlements.

In arid regions where water scarcity drives up the cost of municipal water, low income families living in informal settlements often find it difficult to pay their high water bills. Since rain provides the most abundant source of easily accessible freshwater in such regions during the rainy season, rainwater harvesting may be the best method for creating an alternative/supplemental supply of water. Once implemented, this alternative supply can then, depending on usage, offset the cost of municipal water. The only cost associated with water harvesting is the initial cost of materials and construction. Once a system is properly in place, it should require little or no maintenance and thus provide a free water resource.

Aside from material costs and construction, there are several social challenges involved with successfully implementing rainwater harvesting systems. Often, people most in need of such systems are slow to embrace them, due to a variety of social factors. In order to successfully stimulate interest in rainwater harvesting, a community must be fully engaged in the process, from planning to implementation.

2.4 Community Engagement

Engaging communities and fostering a sense of ownership is vital in development projects, especially in developing countries and poorer areas. This is done through utilizing participatory research techniques to involve community members in identifying problems and creating solutions. Participatory research has two main goals: to "uncover or produce information and knowledge that will be directly useful to a group of people" and to "enlighten and empower the average person in the group, motivating each other to take up and use the information gathered in the research"(Berg, 2007).

Participatory research methods, including community meetings, focus groups and on-going community-researcher dialogue, aim to foster the sharing of knowledge, skills and suggestions so that project outcomes reflect the needs and characteristics of the community. It can also be used to "enable local people to seek their own solutions according to their priorities, but also to secure funding, to co-opt local people into the agendas of others or to justify short-cut research within a top-down process"(Cornwall & Jewkes, 1995). As a principle participation is "now commonly accepted to be an important component of successful development programmes" (Mitlin & Thompson, 1995).

Community participation and involvement can also influence government agencies and the policy making process. Participatory development can "reduce information problems for development planners and beneficiaries, increase the resources available to poor people, and strengthen the capacity for collective action among poor and other marginalized societal groups"(Adato, Hoddinott, & Haddad, 2005). This is beneficial for both communities and agencies since greater participation can determine policy deficiencies and short comings quickly and and allow for greater influence on possible solutions. In many cases, community based organizations and NGOs. Work as intermediaries between the two groups, allowing for more effective communication and more productive interaction.

2.5 Organizations

Despite its best efforts, the government of Namibia does not always have sufficient resources to provide for all of its citizen's needs. Generally speaking, "Community organizations working with local NGOs have been responsible for many of the most cost-effective initiatives to improve and extend provision for water and sanitation to low-income urban households" (Satterthwaite, McGranahan, Mitlin, n.d). There are several NGOs in Namibia dedicated to supplementing the government's role in improving the lives of those who live in informal settlements by empowering these communities to take direct ownership over their situation.

One of the main organization's involved in community empowerment is the Shack Dwellers Federation of Namibia (SDFN). Founded in 1987, the SDFN aims to "be a people's organization and concentrate on practical activities that result in easier access to resources and making a change to lives of the poor" (SDI, 2000). Through their network of 10,000 households nationwide, and with involvement in 350 savings groups, new opportunities have been opened up to people who are not served adequately by the government and traditional resources. Savings groups allow residents to save a portion of their income in a community fund for later uses, such as buying land for a new settlement location. By establishing savings groups, loan programs and information sharing between communities, the quality of life for many informal settlement residents has been improved. The focus on sharing information and community resources has helped communities and individuals affiliated with SDFN to build over 1,000 homes and secure land for 61 savings groups comprised of 2,600 households (SDI, 2000).

SDFN is headquartered in the Hakahana settlement, outside of Windhoek, Namibia. At the Shack Dwellers' building, residents from surrounding communities congregate to share ideas for improvement projects and organize savings groups. Participation of residents from a variety of settlements adds to the collective knowledge and strength of the groups, as the free exchange of ideas enriches each individual community's activities. Due to its role as a center for inter-community communication, SDFN is an ideal place to begin a project designed to improve the lives of those who live in the informal settlements. Through the SDFN, information about new projects can be easily disseminated from the federation to community leaders, and then down to the individual level. At the headquarters, leaders can exchange skills and knowledge on how to implement projects such as this one and take those skills back to their respective communities.

Figure 2.5: SDFN Headquarters

SDFN is backed by the Namibia Housing Action Group (NHAG). It was founded in 1993 as a support service organization for community-based housing groups and became a separate non-governmental organization, registered with the government as a trust in 1999 (Namibia Housing Action Group, n/d). NHAG provides logistical and financial support to SDFN by running savings groups, advising group representatives and organizing international exchanges with other groups throughout Africa and elsewhere in the world. NHAG makes many community improvement projects possible by lending out tools, providing transportation, and even distributing construction materials for free or at a nominal cost.

These two groups are the primary advocacy and assistance groups working with informal settlement in Namibia today. Together, they both work to increase the quality of life and resources available to the poorest groups in Namibia. Through NHAG's services, it is possible to set up a sustainable method for obtaining materials and tools in order to complete a rainwater harvesting system. With the help of the Shack Dwellers Federation of Namibia, the reach of a rainwater harvesting project can be increased far beyond what an individual community could accomplish on its own, which makes it an ideal place to introduce the concept of rainwater harvesting.

2.6 Hakahana

The settlement we worked with with was called Hakahana, located on the western outskirts of Windhoek. Hakahana is one of the older communities in the Windhoek area, and exemplifies life in the informal settlements. This similarity to other communities in the city makes it an ideal case study for the potential of rainwater harvesting in Windhoek, as conditions closely match that of most other locations. The homes of Hakahana are constructed from concrete and/or corrugated iron, as well as other found materials. Although all residents have easy access to a municipal water source, many cannot afford a sufficient amount of water for their daily lives. The Shack Dwellers Federation of Namibia's headquarters are located in the center of the community, and Hakahana also works closely with the Namibia Housing Action Group. Despite active involvement with these two organizations, there are several water-related issues that have yet to be resolved.

Water Issues in Hakahana

Hakahana can be divided into several sub-communities, one of which is called Habitat II, which was primarily where this project was focused. Habitat II

Figure 2.6: Hakahana

represents 120 households, divided into sections A, B, C, and D. Although each home in Habitat II has its own water tap, the community has collectivized their water expenses. Water usage is monitored by NamWater via 2 meters, one for blocks A and B, the other for blocks C and D. The costs are then combined and divided evenly between all households, regardless of individual water usage. After taxes and fees, each home pays about N$50-100 a month for water. Unfortunately, this cost can skyrocket to as much as N$300 when pipes leak or malfunction. Most people cannot afford to pay this much for water, which has led the community to become indebted to NamWater. Interest payments on back debts also add to rising water costs. Many people cannot afford to pay for water at all, creating an additional burden for those who can afford to pay. In extreme cases, some members of Habitat II have had their water access cut off by the community water committee for non-payment. Although the Municipality has chosen to allow water service to continue in the community for the time being, it could suspend service at any time due to outstanding debt. Due to the water-stressed nature of the Habitat II, several community members have expressed interest in creating an alternative water resource.

Water scarcity is a global problem that affects many of the world's most impoverished people. In Namibia, many impoverished people cannot afford to pay for water to meet their daily needs. Although Namibian water policy recognizes the right to a base-level of clean water, public policy often defers responsibility to the community level. In order to alleviate these problems, harvesting rainwater from rooftops can greatly offset municipal water usage.

In case studies involving projects in informal settlements, it has been found that community involvement is a major factor in the success and adoption of similar projects. In Windhoek, there are several support organizations dedicated to providing logistical support to communities for projects such as these, including the Shack Dwellers Federation and Namibia Housing Action Group. By developing a participatory approach with the full involvement of the community and these support organizations, we planned to empower the people of Hakahana to take ownership of their water scarcity problem in developing a sustainable solution. From our background research, we developed several objectives designed to best achieve that goal.

2.7 Objectives

In order to address the issues discussed in the previous pages, we established several objectives to guide our project, each of which will be described below.

Determine the amount of water that can be collected:

This included analyzing rainfall data and trends, as well as evaporation rates, for the City of Windhoek. Data on harvest potential was vital in determining the amount of storage needed, as well as determining whether or not a water harvesting system would be worthwhile.

Assess current rainwater harvesting technologies:

Since resources in the informal settlement are limited, it was necessary to adapt current technologies for rainwater harvesting to utilize readily-available materials, at the lowest cost possible. For a solution to be considered effective, the money saved by harvesting water must outweigh the cost of materials and construction.

Engage community interest in order to identify possible harvesting solutions:

Since this project's focus was to provide a sustainable, alternative water resource, it was necessary to know what purposes this extra water would be used for. Exploring both what the most common uses for water in the community were, as well as what residents would like to use harvested water for, better informed which solutions could provide for these activities.

After coming up with a set of possible solutions, we then presented these recommendations to the community. Determining which solutions worked best for the community was important because if it was not easy to maintain as well as cost efficient, it would not fulfill the community's needs. Also, if it was not easy to replicate, the community would not be able to set up more systems after we left Namibia. Only with the community's consent could a solution work and be further developed.

Implement solutions with the community:

Beginning with a pilot system at the Shack Dwellers Federation's headquarters, we planned to implement as many prototype water harvesting systems as possible in the surrounding area. By starting at the Shack Dwellers Federation, we hoped to establish a launching pad through which we could empower the settlement to take action in implementing a sustainable, reproducible solution on their own.

Develop a manual for future implementation:

Along with physical examples of how to implement water catchment systems, we developed educational resources to address water harvesting in the form of an instructional manual. These manuals served as an aid for spreading the project to new communities. The handbooks would be distributed via the Shack Dwellers Federation, or by people in the community, to any interested party.

Chapter 3

Methodology

3.1 Introduction

In order to obtain the data necessary for this project to be successful, several sources and methods of data collection were used. Reviewing archival data and pertinent literature, conducting site-specific research, and utilizing participatory research techniques were vital in fully understanding the situation in Namibia and gathering the necessary information to complete our objectives.

By using various sources for background research and consulting several agencies, we were able to determine the issues and problems that are involved with developing a rainwater collection system. Using archival data and pertinent literature helped us to understand the background factors that contributed to the water scarcity problem in Namibia. Site-specific data enabled us to understand the context in which we were working in and the pertinent facts about Namibia and informal settlements. Participatory research methods involved the Hakahana community in our work and informed us about the needs and capabilities of the community.

Detailed below is an overview of the three major research methods and their importance to this project followed by a description of our methodology by objective:

3.2 Literature Review and Archival Data

Our project built upon the collective knowledge already established in journals, reports, surveys and other forms of research through using literature review. Utilizing literature review allowed us to assess the current state of research as well as strengths and weaknesses that exist with published literature in our fields of inquiry. Literature Review involves both information seeking and critical appraisal in order to identify appropriate and unbiased work upon which to base further inquiry and study (Taylor, n/d). Understanding published materials helps justify why a project is being investigated by pointing out flaws in the current literature or areas that have not been studied (Obenzinger, 2005).

Though most of this information was non-specific to our location of study, there were several archival data sources that enriched our understanding of the overall situation and provided specific facts and figures about demographics, land, and climate. Having quantitative data helped to establish a common base of knowledge to help make our case, as well as justified our research and solution decisions. A number of sources provided us with a context for developing research questions and understanding the problem holistically.

Since community participation in the developing world and rainwater catchment are two research issues of great interest globally, there were many case studies in publication that we examined. The most useful sources from were international organizations comparing situations and projects from across the world. Furthermore, publications found at the Polytechnic of Namibia library greatly enhanced our research, as they focused on issues specific to Namibia. These texts, which were not available to us during our project preparation, helped us to understand the specific constraints and factors involved when developing a rainwater catchment system.

There are, however, some limitations to utilizing literature and archival data. Often, facts and figures published in older books and articles may be outdated and misrepresent the current situation. In addition, there is a lack of published materials directly relating to Namibia and specifically Windhoek's informal settlements. For this reason, descriptive published data on several of the areas we needed to research was scarce and difficult to obtain.

Reviewing existing policies and policy analysis was an important part of our understanding of this situation. We obtained and reviewed several existing documents authored by UN agencies and other non-governmental organizations that examine Namibia's water policies and how they affect the society at large. These documents have been invaluable in our research and have provided greater understanding of a complex and at times confusing issue. By reading already establish and recognized literature in the field, we created a firm base of knowledge upon which to ground the rest of our investigation. However, there was still a great deal of unpublished information specific to Windhoek that needed to be procured on-site.

3.3 Site-specific Research

Since it was difficult to obtain exact information about our research areas prior to our arrival in Namibia, much of the specific information on the project needed to be obtained on site. Information relating to site topography, local climate, community organizations, settlement life and culture, and policy details were all useful in further clarifying project goals and objectives; even informing them as our project focus shifted.

The bulk of our background research in Namibia involved contacting local experts in the areas of water, housing, and agriculture. By consulting with people who have expertise in these fields, we were able to develop an understanding of the issues facing Namibia, the informal settlements, and possible solutions. These experts, affiliated with the City of Windhoek, the UN Food and Agriculture Organization, UN Development Programme, the Polytechnic of Namibia, and others have been one of our greatest resources.

Since access to information on local community organizations is limited, it was also important to learn how these organizations are structured in order to develop a participatory approach to our project by meeting with representatives. Through contact with the Shack Dwellers Federation of Namibia (SDFN) and the Namibia Housing Action Group (NHAG), we were able to learn about their roles in community life and development.

Overall, our most useful research in Namibia was conducted in the Hakahana settlement. Though reviewing literature and talking with experts informed our understanding of many issues and helped our project as a whole, none of this research would have been relevant without seeing the settlement fist-hand to get an idea of the issues that residents face. Empirical data framed our understanding of water scarcity , for example, but talking with residents and asking them about water usage in relation to their households and community let us know more about what the exact problems and issues facing the settlement were. The citizens of Hakahana have a better understanding of their situation than any outside expert or researcher, and were kind enough to give us some insight into how their community works and some of the struggles they face, especially with water. By asking individual households about rainwater catchment, their interest level and their potential uses of extra water, we got a better idea of the community's wants and needs when developing a collection system and the requirements it must fill.

3.4 Participatory Research Techniques

When working in Hakahana, we utilized several participatory research techniques. These methods have two major goals: to "uncover or produce information and knowledge that will be directly useful to a group of people, through research, education and sociopolitical action" and to "enlighten and empower the average person in the group, motivating each one to take up and use the information gathered in the research"(Berg, 2007). Participatory research techniques are the most appropriate research methods for this project as they allow community members to be highly involved in the creation of a solution that will directly impact their lives. We utilized the consultative mode of participatory research, in which residents were asked for their suggestions and input before our work began (Cornwall & Jewkes, 1995).

Ideally, the collaborative mode of participatory research, where researchers and community members work together on a researcher-designed project would have been utilized. However, due to several constraints present at the settlement, this was not possible. Though this method is the most effective for this project, there are constraints that needed to be understood and taken into account when proceeding with the research process. These include selective participation, where the most involved and vocal members of the community take a larger role in the project than others, gate keeping by local elites, where access to individuals and areas is restricted by community leaders, and excessive pressure for immediate results (Botes & van Rensburg, 2000) By using another method or not including residents in the development of a material solution, the sense of ownership and empowerment would not have been instilled and the likelihood of this project's continuation would have been decreased.

Participatory research methods utilized for this project included holding community meetings, conducting informal surveys, and discussing the problem and possible solutions with community members. Community meetings gave our group the opportunity to explain the goal of the project and how we intended to proceed. During these meetings, we were able to hear concerns people had and answer questions about rainwater harvesting and how it could impact their homes as well as see who was interested in taking an active role in the early stages of the project. Through informal surveys, we received quantifiable data regarding the community's wants and needs when developing a rainwater harvesting system. Perhaps the most important method we used involved informal conversations with residents. When constructing a system or touring the settlement, discussions with community members allowed us to discuss our project and create interest and knowledge about rainwater harvesting.

A major problem with participatory research is that it requires active involvement and input from community members. There can be a high degree of skepticism in the community as to whether it is worth investing time and effort into the project (Cornwall & Jewkes, 1995). Utilizing these techniques can be difficult in poorer areas, like informal settlements, where people are busy simply securing the basic necessities for living. Also, this form of research assumes that "communities" are homogeneous and all have the same ideas, perceptions, and beliefs. Communities are rarely cohesive units and often have subgroups and competing interests (Cornwall & Jewkes, 1995). Interest and participation can also wane if community members see that the project is taking a direction they were not expecting, or if their original ideas about the project are not followed through. All of these concerns were considered when developing our participatory research methods.

3.5 Research Methods

Based on the aforementioned research methods, we took the following steps to introduce and implement water harvesting methods to the settlement of Hakahana:

Determine the amount of water that could be collected:

In order to determine whether or not a rainwater harvesting system would be worthwhile for the people of Hakahana, as well as to estimate the amount of storage necessary, we first needed to determine the amount of water that could be collected from an average sized roof in the settlement. To do this, three types of data were considered: rainfall data, average roof size, and runoff coefficients.

To acquire rainfall data, the group contacted the City of Windhoek's Office of Meteorological Services. The office monitors, among other things, rainfall levels and trends for Windhoek. The office was able to provide our team with daily rainfall levels for the past 94 years along with information on rainfall intensity. Software was then used to graphically represent rainfall levels and determine trends in the data.

Average roof size was calculated through field research in Hakahana, by measuring the horizontal length and depth of several cinder-block home roofs. We measured the roof dimensions on this type of house because formalized houses are best suited to retrofitting gutters and a rainwater collection system, and also represented the majority of the homes of the people that expressed interest in the project. Most of these homes were built through NHAG initiatives and therefore follow almost identical designs, making them virtually the same size. Taking measurements from house to house also gave our team an additional opportunity build a relationship with the residents of Hakahana.

Runoff coefficients account for spillage, leakage, infiltration, catchment surface wetting, and evaporation (Gould & Nissen-Petersen, 1999). Runoff coefficients were acquired through a combination of archival research and interviews with experts at the Habitat Research and Development Center in Windhoek. Since these experts dealt specifically with Namibia, it was decided that the figures they provided would be more appropriate, as coefficients found with archival research were not specific to Namibia. Also, the coefficients found with archival research were slightly higher than the Namibia-specific numbers, so by taking the Namibia-specific numbers our water harvesting estimates would be more conservative.

By critically analyzing archival data, on-site research, and interviews, we were able to determine accurate values for rainfall, house size, and runoff coefficients. These values dictated how much water could be collected using a roof as a catchment surface. From there, it was then necessary to assess current rainwater harvesting technologies in order to determine how to best collect and store rainwater.

Assess current rainwater harvesting technologies:

Before deciding upon a system to implement, it was first necessary to determine what rainwater harvesting technologies were possible to implement in an informal settlement, as well as what would be the most suitable for Hakahana. We conducted background research to determine what systems have been used in other locations throughout the world, including developing countries and urban environments elsewhere in Africa. These materials included case studies and technical reports produced by international agencies such as the UN Food and Agriculture Organization. The cost, materials used, ease of construction, and other major factors were analyzed to determine which systems and components were most appropriate. If any of these factors proved to be problematic, the system would not be feasible for the community. For the purposes of tailoring a system specifically for the residents of Hakahana, we investigated available materials at several local building supply stores. In the hopes of minimizing the cost of the system, we also visited scrap yards to see what materials could be salvaged for free. Items such as gutters, down pipes, and collection containers were vital components to rainwater harvesting systems, all of which had to be easily available and within an affordable price range. If any of the materials were too expensive or difficult to procure, it would be unrealistic for informal settlement residents to utilize them in constructing a system.

Engage community interest in order to identify possible harvesting solutions:

In order to develop a solution that fit the community, it was necessary to determine the interest level in the community and encourage involvement in the decision-making process. In completing this objective, we heavily utilized the participatory research method. Through conducting community meetings and informal interviews with the residents of Hakahana, we gathered more information about the needs of the community and their requirements for a rainwater collection system.

Figure 3.1: Informal Interview With Stakeholders

To engage the community, we presented our project at a group meeting to determine who was interested in the project, as answer any questions or concerns community members had. Next, we conducted informal house to house surveys to better understand the water needs of the community, using purposive sampling. Purposive sampling involves selecting survey subjects by human choice rather than random sampling (White, 1998). We surveyed individuals who were actively involved in this project from the beginning and people we were introduced to in the community rather than a general sampling of the community as a whole. Although using random sampling would have been ideal because it is more representative of the stakeholders, due to the time constraints of this project, the large size of the settlement, and the lack of community organization, conducting a survey using random sampling was not possible. We are confident, however, that because the individuals interviewed were highly interested in rainwater harvesting, the data we obtained represents the ideas of the population segment most likely to use a rainwater harvesting system.

Implement solutions with the community

Initially, we wanted discuss the possible options for rainwater harvesting systems with the community in order to determine what kind of system they thought would be most feasible for the community and their households. However, the community wanted to see action taken before deciding which direction to proceed in. After getting an idea of the general needs of the community, we moved on to researching the implementation of the harvesting system.

Figure 3.2: A Resident Offers Some Advice

Although the participatory approach was being used throughout the project, it was important to emphasize it at this stage, so that people would be able to take what they had learned and apply it to their own homes. This would be done by simply asking community members how they thought the system should best be constructed, allowing them to develop a plan for constructing the system on the Shack Dwellers building and merging that plan with our own knowledge of how the process should be performed. After the plan was developed with the community, we then began construction. This pilot system showed the community how an effective system could be implemented.

It was also necessary to find reliable sources for materials and to arrange for the reliable transportation of supplies. These consistent sources for materials and transportation could then be used to set up a sustainable supply chain so that the project would be continued by the residents.

Develop a manual for future implementation:

In order for this project to be continued into the future, it was necessary to create educational materials so that people not directly involved in this initial project could build rainwater harvesting systems. To create these materials, we examined other educational materials to better understand the most effective and appropriate ways to transmit information. The materials we reviewed included past manuals on erosion control and water education designed for informal settlement residents. Reviewing the best practices from the construction methods we developed and the optimal materials, we were able to provide a guide to the creation of a system which residents could adapt to their homes. The final instructional manual illustrated standard methods for creating a system was made available to all residents interested in creating a rainwater collection system for their homes.

In addition, leaders were trained at community meetings so that community members could help one another with installing systems. This ensured that people with the necessary skills to drive further implementation would remain active in the settlement after the project concluded.

The research approach for this project was greatly dependent upon resources available in Namibia, including experts, archival data, field research, and most importantly, interviews with the residents of Hakahana. Through utilizing background data, we were able to understand the context of our project and that factors that would affect our work. Discussing our project with various experts in Windhoek helped to direct our research and work as well as enhancing our understanding of the issues involved in our work. The most important part of our research was interacting with the residents of Hakahana, discovering their needs, wants, and capabilities, ultimately creating the method for constructing a rainwater collection system that was feasible for the community. This project was only able to succeed by adopting a participatory method thereby actively involving residents in all stages of our work, from initially describing the project, to developing an appropriate solution to implementing the pilot program.

Chapter 4

Results and Findings

4.1 Introduction

The following chapter details the results and findings from our investigation of the viability of rainwater harvesting in Windhoek. An analysis of rainwater harvesting potential showed that the amount of water harvested by a rainwater catchment system could significantly offset municipal water usage. From there, community needs were looked at to determine what harvested water would be used for and how much money people would be willing to spend on a system. Based on rainwater harvesting potential and community needs, we were able to determine what types of materials and methods were appropriate for constructing rooftop rainwater harvesting systems in the informal settlements.

4.2 Rainwater Harvesting Potential

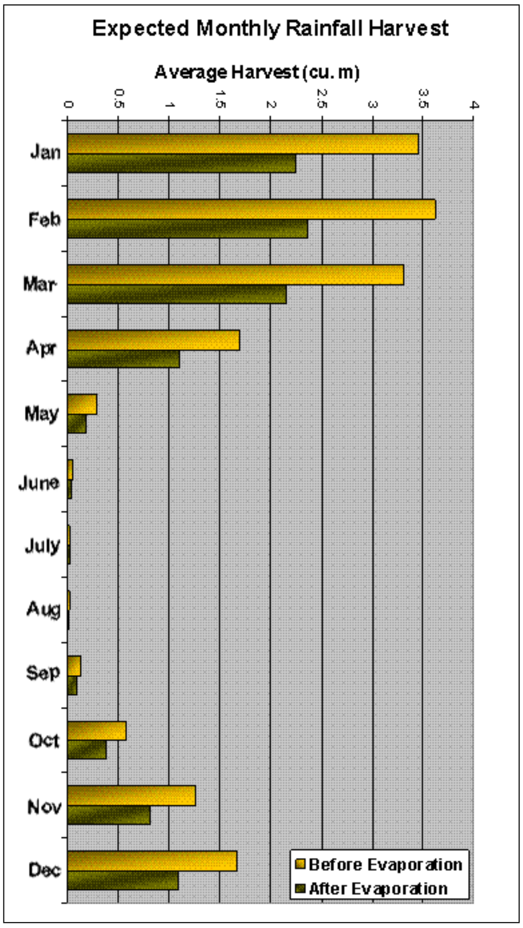
The amount of water harvested by a rainwater catchment system can significantly offset municipal water usage, given that the harvesting system has enough storage. In order to determine this, we examined at rainfall statistics and water consumption habits for the Windhoek area.

Rainfall

In order to determine the amount of rain that could be harvested from a settlement roof, we first examined daily rainfall data for the last 94 years from the Windhoek Bureau of Meteorological Services. We then calculated average roof size in the settlement by taking field measurements of homes. Taking into account the average runoff coefficient, we estimated the amount of water that could be collected during each month with the following formula:

Rainfall x Roof Area x Runoff Coefficient = Water Supply

Even after taking into account the significant runoff coefficient (0.65), during the rainy season of January to March we found that it would be possible to harvest well over 2,000L in a single month. While harvests during the dry season would be negligible, months of moderate rainfall could still produce significant amounts of water (1,000L):



Windhoek Rainfall 1913-2006		
Month	**Ave (mm)**	**Supply (L)**
January	77.4	2,250
February	81.53	2,350
March	74.6	2,150
April	38.17	1,100
May	6.59	190
June	1.18	30
July	0.6	20
August	0.51	20
September	2.95	90
October	12.97	370
November	28.31	820
December	37.53	1,080
Total	362.7	10,480

Storage

In order to find out how much storage would be necessary, we examined rainfall intensity and water consumption habits in Habitat II. Of all of the components of a harvesting system, storage is by far the most expensive[1]. When considering the value of a rainwater harvesting system, taking into account the cost of storage is a major factor. In order to determine the cost of storage, we first had to estimate how much rainwater could accumulate on a daily basis, and then take into account how much water the average household consumes in a day.

Rainfall Intensity

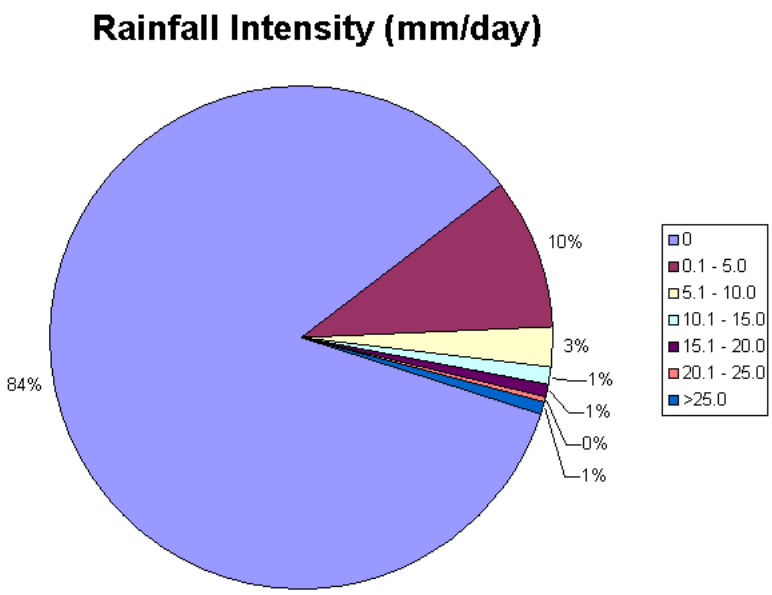


Figure 4.1: Windhoek Rainfall Intensity Distribution

On average, it rains in Windhoek 56 days of the year. Of those rainfall events, 64% produce 0.1-5.0mm of rain, meaning that a single household

[1]For a detailed look at the cost of harvesting components, refer to Appendix B

could harvest up to 144 litres in a single day. In the most extreme case, a rainfall event of more than 85mm in a day could produce over 2,400 litres, but such an event has only occurred once in the last century. The highest significant rainfall intensity is the 25.1-30mm range, with such an event occurring on average once a year. With this intensity, a resident of Habitat II could expect to harvest between 735 and 866 litres of water. On days of consecutive rainfall, even moderate intensities can produce well over 1,000 litres in a few days. However, the need for a large amount of storage can be minimized if a household regularly uses harvested water.

Water Consumption

We attempted to obtain data about average household water consumption from several different sources. When residents were asked how much water their household used on a regular basis, all 14 interviewed replied that they were not sure. However, most residents were able to identify how much they paid for water, between N$50-100 monthly, as mentioned in Section 2.6.

As our next course of action, we requested community water bills from the Habitat II Water Committee. Since the number of homes on each meter was known by the community leaders (60), we could extrapolate average household consumption from the collectivized water usage records. However, the committee was unable to locate the records in the time frame that they were needed.

Since obtaining data through field research proved difficult, we instead turned to archival data from the City of Windhoek's Bulk Water and Waste Water Division. After gaining access to Habitat II's water meters, we were able to contact the department to look up water consumption by meter number:

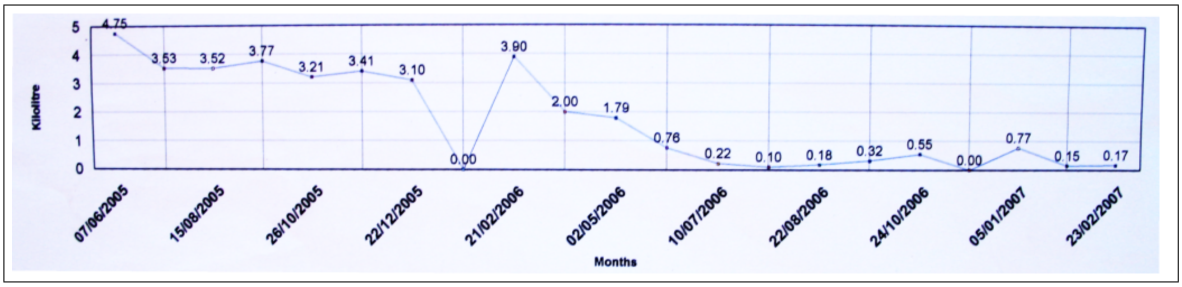


Figure 4.2: Meter #30280717

Meter #30280717 shows consumption from 2005-2006 slightly less than the average reading for meters in Hakahana; 4,470 litres per day. Beginning in February 2006, the meter readings drop off sharply to almost negligible amounts of water consumption. This trend points to an external factor that renders the data inaccurate in predicting average household water consumption.

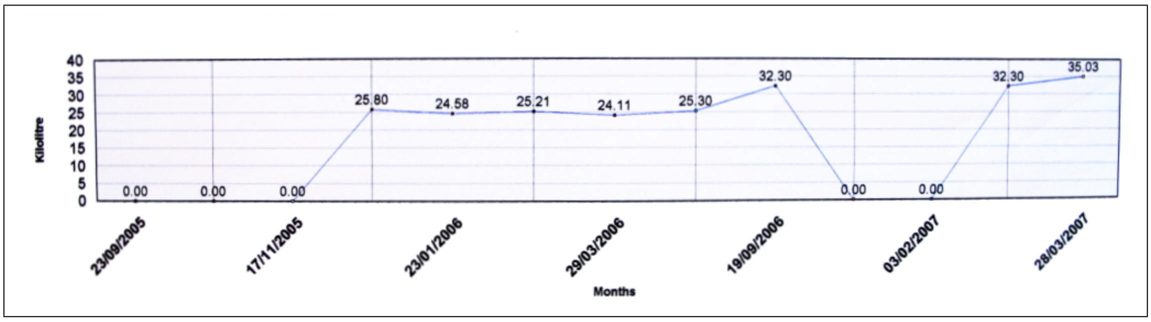


Figure 4.3: Meter #32156816

Similarly, the second meter for Habitat II, #32156816, produced unexpected results. Water consumption alternates between periods of seemingly normal water usage and none at all. Taking into account the large variance in data, the monthly consumption average was 938,640 litres. With this estimate, each of the 60 households on the meter would consume over 520 litres a day. The average water consumption per day for a Namibian living in an urban environment is 150 litres per person per day (IEA, n.d). Given an average household size of 3-5 people, this is in line with national statistics. However, given the large disparity between periods of regular consumption and the zero-consumption outliers, this data could be considered unreliable. Instead, we decided to estimate water usage based on household water payments.

Throughout our research, the only consistent response we received was regarding the monthly cost of water from our interviews with Habitat II residents. Taking into account Bulk Water and Wastewater's water rate for collective communities (N$9.57/cu.m), as well as the N$50-100 range of resident water payments, we were able to estimate that the average household consumes approximately 5-10 cubic meters of water a month, or between 175 and 350 litres per day.

Community Needs

Out of 120 households in the community, 31 expressed interest in collecting rainwater to supplement their water supply. Of the interested residents, 74% were female. The unusually high percentage of interested women represents the community's large number of female-headed households.

In order to get a sense of the community's needs for a rainwater harvesting system, we asked a number of questions during informal interviews regarding what they would do with harvested water, as well as their preferences for harvesting system features. Through this dialogue, community members were also able to ask questions about the project and freely voice their concerns; these concerns were taken into account when drafting a final design.

Water Uses

Potential water usage had a large role in choosing a harvesting system design, as different activities would require varying levels of water quality. During informal interviews with community members, we asked about how the residents would use a renewable water resource from a rooftop harvesting system.

Of those interviewed, nearly two-thirds indicated that they would use harvested water in order to offset or decrease their municipal water usage. When asked about specific water activities, community members indicated a wide variety of potential uses, among them drinking, gardening, cleaning, use in construction, and sanitation. Of these, human consumption of the water was most popular, with small-scale gardening a close second.

Project Concerns

During informal interviews, interested community members voiced a number of concerns regarding the project. Nearly all of the participants surveyed voiced cost as a major deciding factor in their desire to build a rainwater harvesting system. Many community members preferred an individual tank over a communal one, unless there would be significant savings in collectivization.

Some participants cited portability as another concern, as a few homes were being torn down and rebuilt due to pending infrastructure improvements in the settlement. Taking all of these concerns into account, we were able to select an optimal solution that was tailored to the settlement's needs, beginning with available materials.

Available Materials

Before beginning implementation of the rainwater harvesting system on the SDFN building in Hakahana, we first needed to assess materials that were available for use, that is, those materials that were readily available in the Windhoek area. Assessment of these materials included examinations of cost, ease of construction, and effectiveness. Available materials consisted of bought materials, those from hardware and building supply stores, and found materials, those materials that could be obtained from scrap yards. Many of these materials were dismissed because of cost, efficiency, or difficulty of construction. Below is an analysis of various materials that are available in Windhoek, and various material configurations that were considered for implementation:

Gutters

Gutters collect water that falls off the end of a roof and then transfers the water to a down pipe. We found multiple types of gutters that were suitable for a rainwater harvesting system.

Conventional Gutters

Figure 4.4: Conventional Gutter

Conventional gutters are easily accessible from any building supply store in the Windhoek area, at an approximate cost of N$90 for a square, 3.6m long section. Necessary hardware for the installation of a conventional gutter includes a gutter end-piece, which comprises of a down pipe outlet and a water stop, and gutter mounts to hold the gutter in place[2].

The cost to fit a conventional gutter (two 3.6m sections, an end-piece, and about six mounts) on an average sized house in an informal settlement would be approximately N$300. Since the average monthly salary for someone living in an informal settlement in Namibia is N$600 for most households and N$400 for female headed households (SDFN, 1999), a conventional gutter may prove too costly for most people. Due to this prohibitive cost, conventional gutters were not chosen for the pilot project at the Shack Dwellers headquarters.

Found/Recycled Gutters

An alternative to buying new gutters at a building supply store is to recycle old, discarded gutters. Many discarded gutters can be found at the Garden and Building Rubble Center and other scrap yards, which are easy for settlement residents to obtain access to. However, many of the gutters found were folded in half and difficult to unbend. Using tin snips to cut out the irregularities, rather than repairing damaged sections, was found to be a reasonable workaround, albeit time-consuming. Once cut, the gutters were suitable for informal households.

Figure 4.5: Found Gutters

Sheet Metal Gutters

A more affordable alternative for gutter construction is to use flat sheet metal, bent in a V-shape, which acts in the manner as a conventional gutter. Sheet metal can be obtained in 0.9m x 1.8m sheets at a thickness of 0.4mm, making them not only easily transportable, but easy to bend and cut. Sheets

[2]See Appendix B for a detailed list of all gutter and hardware costs

of this size and thickness typically cost around N$70 and are found in most building supply stores. If these sheets are cut in half lengthwise and then each half is bent, a 7.2m long gutter can be constructed for the cost of two sheets; a N$140 cost.

Figure 4.6: Sheet Gutter

The simplest and most affordable means of connecting these sheet metal gutters to a roof was to use cable ties (zip ties). These ties are readily available, durable, easily adjustable, and cost approximately N$37 per bag. The ties can be wrapped around the gutter and then passed through a small hole made in the roof. This system of sheet metal and cable ties proved to be the optimal combination of affordability and simplicity.

Sheet metal gutters can also be made from found sheet metal and even corrugated iron, provided paint and other coatings are stripped from the metal. Sheet metal is a common material in shack construction, and scrap sheet metal can be easily procured by the residents of the settlement. Construction of these gutters follows the same procedure as bought sheet metal gutters, using only cable ties or metal wire for connections. Utilization of found sheet metal gutters decreases the total cost of the system, but can be problematic if the metal is greater than 0.4mm thick. Therefore, found sheet metal thus provides a excellent gutter material if it is clean and malleable.

Down Pipes

A down pipe simply directs water from a gutter into a storage tank, and can be bought or pieced together from scrap.

Conventional Down Pipes

Figure 4.7: Down Pipe

Conventional down pipes are easily accessible from any building supply store in the Windhoek area, and usually cost between N$50 and N$130 for 2.7m sections, depending whether or not the down pipe has a bent end. These sections are simpler to install than the actual gutter and can be configured in a variety of different ways through the use of additional bend pieces. If taking the average cost of a 2.7m down pipe to be N$90, the use of a conventional down pipe with a gutter with a conventional down pipe would be approximately N$390, which again may be too expensive for most people in informal settlements.

Found/Recycled Down Pipes

Figure 4.8: Connected Pipes

An alternative to new downpipes is to use downpipes that are found for free at scrap yards. However, very few downpipes found at the scrap yard were complete. Most sections found were less than a meter long, and complete downpipes were distorted which made them very difficult to utilize effectively. However, the small sections of downpipes can be used to create larger lengths by crimping one end of a section and inserting it into another section. Since this method of construction is simple, and the down pipe sections are free, using found/recycled downpipes is a practical and affordable way of transferring water from the gutter to the storage tank.

Down Pipe with Funnel

Figure 4.9: Down Pipe and Funnel

Connecting the down pipe to the storage tank can be difficult if not using all standardized materials. To remedy this problem, a 5L container can be used as a funnel, collecting the water from the down pipe and directing it into the storage tank. The funnel is created by cutting the bottom off the container and placing it at the top of the storage tank. A piece of mesh is then needed inside the funnel to keep mosquitoes out of the tank. This method is effective, affordable, and very simple to construct.

Storage Tanks

Storage tanks are the most critical part of any rainwater harvesting system. The amount of water that can be harvested is governed by the storage capacity of a container. The storage tank must also ensure the quality of the water. The City of Windhoek stipulates that a water storage tank must be sealed so mosquitoes cannot breed in the tank, and must be black coated as to prevent the growth of algae.

Polyethylene Tanks

Polyethylene tanks are currently the most widely used water storage tanks for formal households in Namibia, specifically tanks manufactured by Okahandja Plastic Converters. These tanks are ideal for rainwater harvesting as they come standard with a down pipe inlet, an overflow outlet, and an outlet for a spout, as well as a black inside coating to prevent against algae growth.

Figure 4.10: Okahandja Tank

Polyethylene tanks are made in a variety of sizes from 400L to 2,500L (tanks up to 10,000L are available, but are too large for household use). 400L tanks cost approximately N$1,380 and the price continues to increase to N$2,270 for 2,500L tanks. Tanks were analyzed in terms of cost per litre to determine which size was most valuable. The 400L tank cost approximately N$3.46 per litre and the value increases to N$0.908 per litre for the 2,500L tank[3]. Even these tanks are of high value and are ideal for rainwater harvesting, but they are still much too expensive for individual families living in informal settlements. For this reason, polyethylene tanks were not viable for use as rainwater storage containers.

Ferrocement Tanks

An alternative to polyethylene tanks is to self-construct a tank. One method of doing this is to use ferrocement. "Ferrocement consists of a cement rich-mortar reinforced with layers of wire mesh" (Holtch, 2007). These materials can be found at any building supply store in the Windhoek area, and can be used to make tanks of virtually any size and shape. These types of tanks are impact resistant, fairly easy to repair, and lightweight when compared to storage capacity.

Figure 4.11: Ferrocement

[3]See Appendix B for a complete list of polyethylene tank sizes, costs, and cost per litre

The construction of ferrocement is labor intensive and requires basic cement mixing and plastering skills. Ferrocement costs between N$135 and N$200 per square meter for all materials needed. If a square, cubic meter tank were to be constructed (this tank shape would be impractical, but the analysis it provides an important cost information), the cost would be over N$1000. Since this project emphasized a simple, do-it-yourself construction method that required little to no experience, the use of ferrocement was impractical.

200L Drum Tanks

Figure 4.12: 200L Drum

200L drums, which are typically used to store oil, tar, and paint, can also be used to store water if lined with black plastic. Discarded drums can be easily acquired for free at most scrap yards and can also be obtained from various companies who wish to dispose of their used drums. Black plastic lining is needed to prevent leakage, algae growth, and contamination from any leftover material still in the drum. Thoroughly cleaning the drum can further prevent against contamination as well.

If there is enough ground space, multiple drums can be easily configured to store 1000L of water or more. Many drums come with both a top and bottom, so a removable cap can be easily constructed by cutting one end. Caps for open drums can be constructed simply using sheet metal or a layer of black lining. In both cases, holes need to be cut in the cap to allow for a down pipe or funnel. This type of tank is durable, simple to construct, and has a fairly large capacity if multiple tanks are used.

An analysis of rainwater harvesting potential showed that the amount of water harvested by a rainwater catchment system could significantly offset municipal water usage. Even just a few days of moderate rainfall could produce well over 1,000 litres of water from an average sized roof. From here, community needs were looked at to determine what harvested water would be used for (mostly gardening, cleaning, and human consumption) and how much money people would be willing to spend on a system. Rainwater harvesting potential and community needs then informed what type of materials and methods were most appropriate for constructing a rainwater harvesting system in informal settlements. The proceeding findings section illustrates these materials and methods.

4.3 Findings

After an assessment of the rainwater harvesting potential, community needs, and available materials, it was determined that:

- The amount of water harvested by a rainwater catchment system could significantly offset municipal water usage;
- The most feasible rainwater harvesting system was one that consisted of found or recycled materials.

Both the design and method of construction for the rainwater harvesting system were tailored around the specific needs of of those living in informal settlements.

System Configurations and Costs

The materials described earlier can be mixed and matched in a variety of ways to construct a rainwater harvesting system. Bought materials can be combined with found materials to decrease the cost of a system while maintaining efficiency. The following tables detail three different system configurations:

Harvesting System 1 is an ideal system using all bought materials and was used as a benchmark for all other systems. This system is expensive and more difficult to construct, but is also highly effective as all the materials are manufactured for the purpose of collecting and storing water.

The next two systems present the most simplistic, while still effective, alternatives to an entirely bought system. System 2, is a system using bought sheet metal gutters, a spout and funnel down pipe, and oil drum storage tanks. System 3 is similar to the System 2, except it uses found sheet metal gutters instead of bought sheet metal gutters. Other combinations of materials can be used, such as conventional gutters with found tanks or found gutters with polyethylene or ferrocement tanks, but these configurations add to the complexity and cost of the system.

System 1: Bought Materials		
Material	**Quantity**	**Cost (N$)**
1,000L Tank	1	1,391.00
Gutter	2	90.00
Gutter Endpiece	1	65.00
Gutter Mounts	6	10.00
Down Pipe	1	90.00
Total:		1,786.00

System 2: Bought Sheet Metal		
Material	**Quantity**	**Cost (N$)**
Oil Drum	Multiple	Free
Plastic Lining	4	10.95
Sheet Metal	2	70.00
5L Container	2	Free
Cable Ties	1	36.95
Total:		220.75

System 3: Found Materials		
Material	**Quantity**	**Cost (N$)**
Oil Drum	Multiple	Free
Plastic Lining	4	10.95
Scrap Metal	Multiple	Free
5L Container	2	Free
Cable Ties	1	36.95
Total:		80.75

Based upon average rainfall intensities for the City of Windhoek, a single informal settlement household could harvest about 1,000 litres of water in a few days, and at most 866 litres in a single day. Given that the average household in Habitat II consumes between 175 and 350 litres of water a day, it is reasonable to assume that a storage container with a 500-1,000 litre capacity would be ideal for the settlement's needs.

Taking into account the cost of other building materials, we can compare the cost of a rainwater harvesting system against its benefits.[4] Since the average monthly salary for someone living in an informal settlement in Namibia is N$600 for most households and N$400 for female headed households (SDFN, 1999), a system comprising entirely of bought materials, as in Harvesting System 1, would be too expensive for most settlement residents.

The two most affordable options were Harvesting Systems 2 and 3. System 2 is the simplest to construct; Bought sheet metal is easy to bend, cut, and hang. System 3, using found sheet metal, is slightly more complicated because it may not always be possible to find appropriate sized sheet metal. Found sheet metal can often be too thick to cut or require too much effort to clean. However, if found sheet metal is malleable and clean, it can be used to construct a more affordable harvesting system; one that costs approximately N$80 for materials. This system pays for itself in about six months if there is an average rainy season.

The following tables summarize the benefits and detriments of each system:

Although a system consisting of all found materials is the most cost-

[4]See Appendix B for more information about material cost.

Bought Materials	**Bought Sheet Metal**	**Found Materials**
Most reliable	Simple to construct	Difficult to construct
Prohibitively expensive		Lowest cost
Payoff Period: 18 years	**Payoff Period:** 2 years	**Payoff Period:** 6 months

Figure 4.13: Benefits and Drawbacks of Harvesting Systems

effective, the difficulty associated with adapting the materials led us to choose system that utilized a mixture of bought and found materials (System 2) as a proof of concept. Using bought sheet metal not only minimized construction time for the pilot system, but also contributed to a more aesthetically-pleasing system, which we hoped would create interest in the project. Although it requires more work to construct a system using found sheet metal gutters, we found that for most settlement residents, the cost savings (N$80 versus N$220) and the short payoff period (6 months versus 2 years) outweighs the necessary labor required to build this system.

4.4 Implementation

After working with the community to decide upon an appropriate rainwater harvesting system, construction began on the pilot system at the SDFN headquarters in Hakahana. Through the construction of this system, we were able to develop a method of building that would be best for informal settlements. It was important to keep in mind that this system was implemented in a low income area. This meant that utilization of specialized tools and techniques was impractical.

As stated in the Summary of Findings, we chose to implement System 3 as a pilot system since it was the quickest to construct. This system consisted of gutters made from bought sheet metal and cable ties (zip ties), found downpipes, and storage tanks made from found oil drums and bought plastic lining. This system was simple to construct in little time with only a few tools needed.

Gutter Construction

For the pilot system at SDFN, guttering was constructed using bought sheet metal, to demonstrate the ease of which gutters can be constructed out of a readily-available material. The sheets were 1.8m long x .9m wide and .4mm thick, which was the only size available at Cashbuild. To make the most effective use of the metal, we cut the sheet into two pieces 1.8m long and .45m. Each sheet was then folded, using a hammer to crease the metal, into a V shape, with one side wider than the other. This was done to act as a splash guard, preventing water from running past the gutter during heavy flow. To ensure proper water flow, the gutter was sloped downward by adjusting the length of the cable ties used to fasten it to the roof.

Figure 4.14: Gutter Construction

Down Pipe Construction

The down pipe was constructed using discarded pipes sections that were found at local scrap yards. Sections were connected to form an appropriate length by hammering one end of a down pipe section so that the end decreases

Figure 4.15: Roof Preperation to Hang Guttering

in size, and then inserting it into another down pipe section. The down pipe was connected to the gutter using cable ties, and to the storage container by placing it inside of a 5L container acting as a funnel. Wire mesh was placed inside the 5L container to prevent mosquitoes from entering the tank. By not connecting the down pipe directly to the storage container, we made it possible to easily replace storage containers, as well as to easily remove the top of the container to collect the harvested water.

Storage Tank Construction

Discarded 200L drums, which are typically used to store oil, tar, and paint, were used as water storage tanks. The drums for the pilot system were obtained for free at a local scrap yard, but they can can also be obtained from various companies who wish to dispose of their used drums. The pilot system at the SDFN building in Hakahana only used one drum, but multiple drums can be easily added to the system to increase storage capacity. The drum(s) were placed directly under the gutter/down pipe.

Black plastic lining was needed to prevent leakage, algae growth, and contamination from any leftover material still in the drum. The lining had to be kept loose so that it was not strained when the tank was full. Any material can be used to construct a cap for the tank including the original cap, sheet metal, or pieces of plywood, provided they are covered with another piece of plastic on the bottom to prevent deterioration. In this case, the original cap to the drum was used. A hole was made in the cap to allow the funnel to be inserted. The water could be removed from the storage tank by simply lifting up the cap.

It was found that a system consisting of all new, bought materials was too expensive, approximately N$1,800, with a payoff time of approximately 18 years. A system of bought sheet metal gutters, found downpipes, and found 200L storage drums was much more affordable (approximately N$220) and easy to construct, with a payoff period of two years. This system was chosen as the pilot system because it was the simplest and quickest to construct. However, an even more affordable system is one that utilized almost all found/recycled materials. This system used of found sheet metal for gutters, discarded downpipes, and discarded 200L drums and only cost approximately N$80 with a six month payoff, including the cost of cable ties and plastic lining. This system could be adapted to fit almost any household in a settlement, including both brick houses and shacks. The implementation of the pilot system on the SDFN building in Hakahana proved that the system was easy to construct and effective when

Figure 4.16: Completed Storage Tank

collecting and storing water. Simple construction techniques and few tools were used to construct the pilot system. During a presentation of the pilot system at the SDFN, residents reaffirmed their interest in the project. Based on these results and findings, several recommendations were developed to ensure the sustainability of rainwater harvesting projects in Windhoek.

Chapter 5

Recommendations

In order to facilitate the spread of rainwater harvesting practices, we created several recommendations for community members and non-governmental organizations. If followed, these recommendations are designed to provide a sustainable framework through which rainwater harvesting systems can be easily implemented.

Establish a program to educate and train community members on rainwater harvesting techniques:

During the initial demonstration of our pilot system at SDFN, we found that some settlement residents were familiar with the concepts of rainwater harvesting. A few of the older women in attendance remembered that in the Old Location[1] and on family homesteads, water harvesting was commonly used. However, as those people were forced to move from their land, the knowledge required to implement rainwater harvesting systems were lost. To

[1]The Old Location was formerly a large settlement in Windhoek. As the population of Windhoek grew, people living in the Old Location were forcefully removed in order to make way for a new, white suburban area (Bruer, n.d.).

prevent the knowledge of rainwater harvesting from becoming lost once again, it is necessary to incorporate basic rainwater harvesting techniques into the common knowledge of as many informal settlement residents as possible.

Figure 5.1: Demonstration of Rainwater Harvesting System

We recommend that a program be established to educate and train community members in the informal settlements on the benefits and techniques of rainwater harvesting. With this program, community organizations such as the Namibia Housing Action Group, Shack Dwellers Federation, and students from the Polytechnic of Namibia would work together to conduct regular instructional workshops, or skill shares, to interested communities. The skill shares would provide key community leaders with the training and assistance necessary to implement a rainwater harvesting system, as well as encourage those leaders to further spread this knowledge to others. The skill shares, which would take place at a community meeting place such as SDFN headquarters, should:

- Explain the benefits of rainwater harvesting;
- List the materials and tools needed build a rainwater harvesting system;
- Demonstrate how the rainwater harvesting system works;
- Explain the steps required to build a rainwater harvesting system;
- Encourage community members to work together in order to spread knowledge, procure supplies, and construct harvesting systems;

Community organizations should provide logistical support and assistance to settlement residents in the implementation of rainwater harvesting systems:

The continued implementation of rainwater harvesting systems in the informal settlements will not be able to continue without access to the materials needed to create such systems. Creating a sustainable supply chain, including transportation is vital. Groups like the Shack Dwellers Federation of Namibia and the Namibia Housing Action Group both have the contacts and resources to provide the logistical support needed for future success.

In order to set up a sustainable supply chain, tools used during the project were donated to the Namibia Housing Action Group for the establishment of a tool library. From this library, settlement residents can borrow tools for a short time to construct a rainwater harvesting system. In order to deter theft, we recommend that a small, refundable deposit be charged for the loan of tools. Optionally, a small portion of the deposit could be retained for the purposes of expanding the tool library. In addition to the tool library, NHAG already provides transportation for the cost of petrol to support community-based projects.

Settlement residents should be encouraged to pool funds to arrange for transportation to scrap yards in order to procure building materials and obtain tools. Information about the sustainable supply chain, including how and where to borrow tools, book transportation, and procure scrap material were included in the rainwater harvesting manual. Maintenance of this sustainable supply chain ensures that the resources necessary for settlement residents to complete their own rainwater harvesting systems are easily available.

Include rainwater harvesting systems in designs for future settlement homes:

When building new homes, a small portion of the home's funding should be allotted for the construction of a rainwater harvesting system, and incorporated into the standard informal settlement dwelling design. During community construction, building materials such as concrete and sheet metal are widely accessible, and most of the expenses and logistics dealing with material procurement and transportation have already been accounted for. Additionally, community members are typically very active in the construction of new homes. Organizations involved with building new communities, such as NHAG, should take advantage of this window of opportunity by utilizing the community's eagerness to get involved during initial home construction.

Incorporate rainwater harvesting into urban agriculture projects:

Rainwater Harvesting techniques can be used to improve many community projects, including the UN Food and Agriculture Organization's Urban and

Peri-urban Agriculture program. Currently, the program works with community members to develop small-scale agriculture in the informal settlements of Namibia. The program stresses the importance of water conservation, using hydroponic techniques and drip irrigation to minimize water usage. Due to this focus, rainwater harvesting can be used to enhance the program's sustainable irrigation systems. In the interest of incorporating rainwater harvesting into the program, we established relationships with several members of the UNFAO, and submitted educational materials and information on rainwater harvesting to the FAO's public agricultural knowledge base, Hortivar[2].

The participation of non-governmental organizations in the process of implementing rainwater harvesting systems is crucial to the continuation of this project. These organizations must take an active role in training settlement residents, maintaining a sustainable material supply chain, and in the implementation of rainwater harvesting systems in future homes. Ensuring that key community members have the knowledge and skills necessary to implement a rainwater harvesting system will also guarantee that they will be able to pass down that knowledge to others. By setting up a system through which interested settlement residents can easily obtain tools and materials, it can be assured that lack of resources will not prevent any person from being able to harvest water. Finally, incorporating harvesting systems in future homes and urban agriculture programs will help to institutionalize the concepts of rainwater harvesting, guaranteeing all new settlement residents a basic amount of water, regardless of their ability to afford municipal water.

[2]For more information, visit `http://unfao.org/hortivar/`.

Chapter 6

Summary

Water scarcity is a global problem that affects many of the worlds most impoverished people. Namibia is currently experiencing the effects of water scarcity, as arid climate and other social factors exacerbate growing demand and short supply. The Namibian government recognizes access to water as an inalienable right. However, the costs of providing such water is high. As a result, many impoverished people living in informal settlements cannot afford to meet their water needs. In order to alleviate these problems, harvesting rainwater from rooftops can greatly offset municipal water usage.

With the assistance of the community of Hakahana, we were able to design and implement a rainwater harvesting system that took into account the settlement's needs. The system, which harvests rainfall from rooftops into a recycled storage container, can potentially provide settlement residents with over 10,000 litres of water a year, providing a significant, renewable water resource to offset municipal water usage. By using recycled or found materials, the cost of the system can be minimized to as little as N$80, an amount that can be recovered through water savings from a single rainy season.

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Chapter 7

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Appendix A

Informal Survey Questions

The following questions on water usage habits were asked during informal, face-to-face interviews with members of the Hakahana community. Interviews were conducted in Afrikaans and translated by Polytechnic of Namibia students collaborating on this project:

Q: How much do you pay for water, per litre?

Q: How much water do you use in an average day?

Q: If you had a small supply of free, surplus water, what would you like to do with it?

Q: Would you prefer to share a water supply with your neighbors, or would you like to have your own, smaller, collection tank?

Q: How much money, if any, would you be willing to contribute for a rainwater harvesting system that could provide a small amount of free water?

Appendix B

Material Availability and Costs

This section contains information about locally available building materials:

Polyethylene Tanks:

Size (L)	**Cost (N$)**	**Cost per Litre**	**Location**
25	62.78	2.5112	Agra
50	188	3.76	Pupkewitz
100	306	3.06	Pupkewitz
400	1,383.00	3.4575	Agra
900	1,744.00	1.9378	Agra
1000	1,391.00	1.391	Agra
2500	2,270.00	0.908	Agra

Guttering:[1]

Material	**Cost (N$)**
Stainless Steel Gutter (3.5m)	46.95
Flat Sheet Metal (1.8m)	69.95
Corrugated Sheet Metal (3.0m)	103.95
Ferro-cement Concrete (50kg)	56.95
Rounded down pipes (2.7m)	94.95
Square down pipes (2.7m)	128.95
Round down pipes (2.7m)(w/bended spout)	53.95
Square down pipes (2.7m) (w/bended spout)	95.95
Square Crimped Offset	66.95
Round Crimped Offset	47.95
Round Gutter Mount	10.95
Square Gutter Mount	10.95
Gutter-down pipe Connector	62.95
Cable Ties (50x)	36.95
Plastic Lining (1x4m)	10.95

[1]Prices and Availability from Cashbuild hardware store

Appendix C

Water Quality

The quality of water needed greatly depends upon its intended uses. There are two levels of water quality to take into consideration. If harvested water is to be used for small-scale agriculture, household cleaning tasks, and so fourth, it is not necessary to be potable, or acceptable for direct human consumption. Collected rainwater is to be used for drinking, it must undergo some form of purification before it can be considered potable.

There are several methods currently available to purify collected rainwater in order to make it either cleaner for domestic and agricultural uses or potable. A major concern when selecting and utilizing a purification system is the cost and ease of use. The City of Windhoek requires that collected rainwater used for human consumption must be up to the same standard as water distributed by the municipality (HRDC, 2007)). Common purification methods suitable for small families include sand and carbon filtration, chlorination, Pasteurization, and UV disinfection (Gadgil, 1998).

Rapid sand filters involve passing water through a filter bed over a 2-5 hour period, using gravity to passively filter the water. This system cannot ensure potable water, so it must be used in conjunction with another system, such as ultraviolet or chlorine treatment. By using these two systems in conjunction, the vast majority of pathogens, heavy metals and other contaminants can be removed. Slow sand filtration works much like rapid sand filtration but is far more effective. Water passes through a layer of sand at a very slow pace, removing bacteria and other contaminants. Water filtered with this method is generally considered to be potable as opposed to rapid sand filtration which requires a secondary filtration method to be used in conjunction+.

Carbon filters are widely available for both commercial and residential use but present several problems. Though they work quite effectively at removing contaminants, there is a cost associated with this solution as filters need to replaced periodically. In addition, these filters need to be fitted on an tap or other form of spigot, which is not always present at all homes or in all rainwater collection systems.

Chlorine can be added to harvested water (2mL per litre of water), killing bacteria and normalizing the pH (Gadgil, 1998). Using chlorination for large water systems is quite effective and economical since it costs only US$0.02 to sanitize a cubic meter of water. However, for smaller water systems, like communities or a cluster of households, the cost for chlorination can be high, since procuring chlorine through a dependable supply chain can be very difficult in some locations, and anyone handling chlorine must be properly trained.

One of the more widely used and simple methods of water purification is Pasteurization. This process involved bringing water up to a rolling boil (100C) for over a minute (Gagdil, 1998). Though easy and efficient, substantial amounts of wood or other biomass is need to be burned to boil the amount of water necessary for the daily water needs of a household. This material either needs to be collected or bought, adding to the economic hardship already faced by families living in informal settlements. In Namibia where wood and other vegetation is very scarce and important to the ecosystem, this solution is not be practical for regular use from an environmental and economic standpoint.

UV light between 240 and 280 nm has been used for over a century to disinfect water (Gagdil, 1998). Most forms of UV disinfection use fluorescent lamps, similar to those found in many households to kill microorganisms, but using natural UV light from the sun has also proved to be effective. By putting unsanitized water into glass or plastic soda bottles and placing them on the roofs of homes, water can be UV purified over a period of a few days. This modified method is both simple and cost effective.

For any of these water harvesting and purification systems, it is essential that community members understand them and take ownership over their upkeep. "A key lesson learned from rainwater catchment system implementation projects is that the single most important factor in ensuring long-term success relates to the degree to which both individual system recipients and the community as a whole are involved" (Gould & Nissen-Petersen, 1999). If they are involved from the very beginning of the project, the community members can drive the project, instead of a system being imposed on them. A method that is easy to setup, inexpensive, and simple to maintain is necessary if it is to be successful long term in informal settlements. In this manner, a proposed rainwater harvesting system can be sustained in its area of initial construction, as well as reproduced in areas facing similar problems.

Appendix D

History of Namibian Water Policy

After independence, water policy in Namibia changed dramatically, as Namibians gained complete control over their government and resources. The water sector, like many areas of government, was subject to reform after the South African apartheid ended. However, due to the "ad hoc approach and limited scale of reforms and partly owing to the absence of several factors including political commitment, resources allocation and technical capacity, these policy changes have not kept pace with the political, economic or technical capabilities and resources of the country"(Dinar & Saleth, 2005). Skills and resources are being deployed to meet pressing water supply needs rather than creating long-lasting institutional and policy reforms. The majority of investment has gone into ensuring that all Namibians have water while very few resources have been devoted to major institutional changes. According to Heyns (2005), changes have been limited in this respect due to several factors including a lack of political commitment, resources allocation and technical capacity.

Water Policy Changes

There have several major changes to Namibia's water policy since the first major water policy, the Water Act No. 54 of 1956, was dictated by South Africa to what was then South West Africa. South Africa dictated several other policies during the occupation era, which mainly dealt with infrastructural and capability development, not institutional growth or reform. Many measures have been taken since independence was attained in 1990 to deal with both water accessibility and policy. Before 1990, laws and policies were dictated by the colonial power, first Germany and from 1917 to 1990, South Africa. As the vast majority of Namibia's laws and policies were reformed or rewritten after independence, water policy also underwent dramatic changes and re-prioritization.

Giving access to water to all Namibians, especially those in rural locations far from the colonial-era infrastructure was the primary concern of the early post-independence policies. Access to water rose substantially between 1991 and 2001, from 50 to 87 percent, making it a leader in Southern Africa for water accessibility (Bayliss, 2005). It is worth noting that Namibia achieved this impressive gain in accessibility without contributions or guidance from international bodies such as the UN or World Bank, unlike many other countries undergoing major infrastructural changes after gaining independence. As a result, Namibia is free from donor pressure and therefore able to pursue its own policy agenda.

The first two major water policies created in post-independence Namibia were the Water Supply and Sanitation Sector Policy of 1991 and the Water Policy of 1993. The goal of these policies was creating a method for dealing with water infrastructure, processing and development. Policy toward water, as well as the water distribution institutions in Namibia dramatically changed with the Namibia Water Act of 1997 and the creation of the Namibia Water Corporation, or NamWater. With the creation of this act, Namibia decided to commercialize the bulk water supply, in part to reduce the number of government staff members required to run the water system. NamWater, the body in charge of water processing and distribution, is completely owned by the government but operates independent of direct government control. One of the main justifications for its creation was that "the government should not run the core business of a service industry, but concentrate on policies, legislation, regulations and strategies to facilitate development by improving conditions in the water sector"(Heyns, 2005). A number of functions previously carried out by the government, including drilling, maintenance and water testing, were delegated to private firms. In urban areas, such as Windhoek, NamWater sells to the local municipality which then provides water to households and businesses.

When NamWater was created, citizens were charged for water both to make water processing and distribution financially sustainable and to encourage water conservation and responsible use (Bayliss, 2005). Until this time, the government completely subsidized water for the whole country. Cost recovery and decentralization were two of the government's major goals when creating NamWater, changing the way Namibians got their water. The price of water has increased and subsidies are being decreased to zero since the policy of full cost recovery has been adopted. This major policy transition has been difficult not only on the government but also on citizens.

A major addition to Namibia's water policy was the National Water Policy of 2000. This policy was designed to complement, not replace the Water Act of 1993. The basis of their policy was the Dublin Principles created in 1992 which state (Heyns, 2005):

- Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment
- Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels
- Women play a central part in the provision, management and safeguarding of water
- Water has an economic value in all its competing uses and should be recognized as an economic good (The Dublin Statement on Water and Sustainable Development, 1992)

By taking an integrated water resources management approach, Namibia worked within a framework for equitable, efficient and sustainable water resources management that is perfectly in line with internationally accepted best practices(Heyns, 2005). One of the main goals of this policy was to improve and increase both functional and management capacities to meet growing water management challenges, including environmental, social, economic and legal issues.

The latest act, the Water Resources Management Act of 2004 outlines government jurisdiction of water as well as the supply and use of this resource. This latest policy, as well as the preceding acts, aim to improve Namibia's management, distribution, and use of water. The fundamental idea behind this legislation is to ensure that all Namibians have access to water and clarify the government's role in water management and regulation. It states that the Ministry responsible for water must see that "all Namibians are provided with an affordable and a reliable water supply that is adequate for basic human needs"(Government of Namibia, 2004). Also, Part VII, Section 31, Right to collect meteoric water states, "A person has the right to collect meteoric water collected on his or her own land or the communal land for domestic use." This section established the right to collect rainwater for personal use, one major way to alleviate the water shortage in Namibia. In addition, the City of Windhoek permits rainwater harvesting as long as two conditions are adhered to. First, the system must not be connected to the municipal water supply and measures must be taken to make sure mosquitoes are not breeding in the tank (HRDC, 2007).

Though this idea and the spirit behind the law is aimed to assist Namibia's development and necessary is for Namibia's continued growth and development, it is not complete. Much still needs to be established within the government to ensure that all citizens, regardless of their socioeconomic status will have consistent access to clean reliable water.